in the order it was requested.

DEPR:
The preprocessing step is now described with respect to FIG. 9. The
preprocessing algorithm's goal is to provide the fastest response to the user's
request to interact with the image. Once this fast computational step is
performed, the server 120 is able to provide efficient Pixel-On-Demand.TM.
transmission of any client ROI requests that will follow. In most cases the
first ROI is a view of the full image at the highest resolution that fits the
viewing device. The preprocessing algorithm begins with a request for an
uncompressed **image that has not been processed** before or has been **processed** but
the result of this previous computation has been deleted from the cache 121.
As explained, this unique algorithm replaces the possibly simpler, yet less
effective, procedure of encoding the full image into some progressive format.
This latter technique will provide a much slower response to the user's initial
request then the present technique described below.

ORPL:
Article entitled "RSNA vendor showcase wealth of Web-based **teleradiology**" by
Michael J. Cannavo, published in Telehealth Magazine, Feb., 1999.

DOCUMENT-IDENTIFIER: US 6314452 B1
TITLE: System and method for transmitting a digital image over a communication network

DEPR:
Unlike other more traditional applications or methods which **perform** fill progressive encoding of the image in an offline type manner, the goal of the preprocessing step 202 is to allow the **server** 120, after a relatively fast computational step, to serve any ROI specified by the user of the client computer 110. For example, for a 75M RGB (color) **image,** using the server 120 of the present invention, installed on a computer with a Pentium **processor,** fast disk 122, running Windows NT, the preprocessing step 202 will typically take 5 seconds or less. This is by order of magnitude faster than a full compression algorithm such as is described in the prior art, such as in J. M. Shapiro, "An embedded hierarchical image coder using zero-trees of wavelet coefficients", IEEE Trans. Sig. Proc., Vol. 41, No. 12, pp. 3445-3462, 1993; A. Said and W. Pearlman, "A new, fast and efficient image codec based on set partitioning", IEEE Trans. Circuits and Systems for video Tech., Vol. 6, No. 3, pp. 243-250, 1996; or D. Taubman, "High performance scalable image compression with EBCOT", preprint, 1999.

DEPR:
If the ROI is a high resolution portion of the image, the **server** 120, in step 804, reads from cache 121 or **performs** a "local" and efficient version of the preprocessing step 801. Specifically, a local portion of the uncompressed **image,** associated with the ROI, is read from the storage 122, **processed** and encoded. Data encoded in steps 803-804 is progressively sent to the client 110

SEARCH RESULTS [PDF Full-Text (332 KB)] PREVIOUS NEXT

Medical image compression using set partitioning in hierarchical trees for (milit telemedicine applications

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INSPEC Accession Number: 6846763

Abstract:
Imagery is an important source of information both to the military and to the m doctor. To support highly mobile forces, wireless communications are essential this results in limited bandwidths available for the transmission of information, imagery. High quality, maximum compression and fast image coding technique required both by the military and their field doctors for transmission over their bandwidth communications channels. This paper describes our ongoing researc applicability of SPIHT image coding in a (military) telemedicine system. The pe of coding a typical medical image is also compared against the international sta JPEG. Set Partitioning In Hierarchical Trees (SPMT) is a new image coding tech developed by A. Said and W.A. Pearlman (1996), which orders the transform c using a set partitioning algorithm based on the subband pyramid. By sending t important information first of the ordered coefficients, the information required reconstruct the image is extremely compact. This new technique offers significa improvement in compression ratios compared with JPEG, Wavelets and Fractals also one of the fastest codecs available and provides user selectable file size or quality and progressive image resolution and transmission.

Index Terms:
image coding; data compression; telemedicine; wavelet transforms; image res codecs; medical image processing; medical image compression; set partitionin hierarchical trees; telemedicine; military telemedicine; imagery; wireless communications; maximum compression; image coding; SPIHT image coding; international standard; SPMT; set partitioning algorithm; subband pyramid; co ratios; codecs; user selectable file size; image quality; progressive image resol

SEARCH RESULTS [PDF Full-Text (332 KB)] PREVIOUS NEXT

MEDICAL IMAGE COMPRESSION USING SET PARTITIONING IN HIERARCHICAL TREES FOR (MILITARY) TELEMEDICINE APPLICATIONS

Maaruf Ali[1]

Overview

Imagery is an important source of information both to the military[2] and to the medical doctor. To support highly mobile forces, wireless communications are essential. However, this results in limited bandwidths available for the transmission of information, including imagery. High quality, maximum compression and fast image coding techniques are required both by the military and their field doctors for transmission over their limited bandwidth communications channels.

This paper describes our ongoing research into the applicability of SPIHT image coding in a (military) telemedicine system. The performance of coding a typical medical image is also compared against the international standard, JPEG.

Set Partitioning In Hierarchical Trees (**SPIHT**) is a new image coding technique, developed in 1996 by Amir Said and William A. Pearlman, which orders the transform coefficients using a set partitioning algorithm based on the subband pyramid. By sending the most important information first of the ordered coefficients, the information required to reconstruct the image is extremely compact. This new technique offers significant improvement in compression ratios compared with JPEG, Wavelets and Fractals. SPIHT is also one of the fastest codecs available and provides user selectable file size or image quality and progressive image resolution and transmission.

Introduction

A compact light mobile telemedicine system is desirable in the field. The various components of the system should also be cheap, easily available and user-friendly. The system should also be operatable anywhere in the world. Figure 1 shows such a concept telemedicine system.

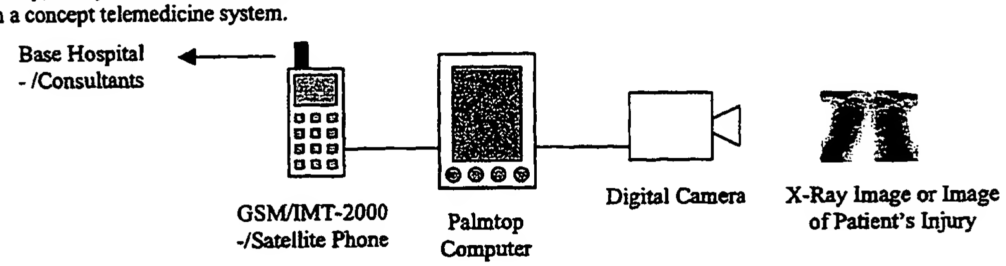

Figure 1. The Concept Telemedicine System.

Several major concerns with military equipment are the factors of: equipment interoperability, replacability and cost. All the devices shown in Figure 1, can be easily integrated, replaced and updated. The total cost of the equipment can easily be met within one thousand pounds at current price levels. One of the earliest telemedicine system of several years back would have cost around £31,750. £28,000 of which was due to the use of an Inmarsat phone.

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[2] SMITHERS, L., & ALI, M., "An Investigation into Image Compression using Set Partitioning In Hierarchical Trees (SPIHT) for Military Applications", *IEE Colloquium on Data Compression Methods and Implementations*, 23 Nov., 1999. Colloquium Digest 99/150, p.3/1-3/4. IEE Savoy Place, London, UK.

System Operation

The system shown in Figure 1 is very easy to operate, requiring very little setup and user training. This last point is important since there is a high turnover of staff in remote locations. The basic operational procedure is that an image is first captured by the digital camera. This image could be an x-ray, an image through a microscope, an ECG scan or the injured person. The image is then downloaded from the camera to the palmtop for further processing, such as image cropping for example. At this stage it is worth mentioning that if the camera does not output a raw format image, then the highest quality JPEG mode of operation could be selected, and then this image could be compressed using the SPIHT algorithm. After compression the image file can then be sent as an e-mail file attachment via the mobile phone to an appropriate Internet service provider. The mobile phone can of course be replaced by a more appropriate transmission system such as military transceivers, satellite phones or even normal land line phones. Simple encryption of the data can also be implemented at the palmtop stage. For urgent cases the doctors or consultants can be communicated with using the phone - telling them to check their e-mail immediately for example.

Image Compression

Until recently most armies passed photographs by hand. With recent technological advances in computing resources it has become possible to import or scan these images and relay them using electronic communications. Wireless communications are essential to support highly mobile forces. However, this results in limited bandwidths and the 'weakest' link in the communication chain is likely to be a VHF link. With error correction, the best data transmission rate achievable with a VHF link using current equipment is 9.6 kbs. Fortunately images contain a substantial amount of redundant information. The setup shown in Figure 1 is perfectly suitable for telemedicine applications as "it has been shown in many studies that the majority of telemedicine advice can be provided using only still images."[3]

Image compression techniques aim at removing redundant and irrelevant information then efficiently encoding the remaining information. However, in practice it is often necessary to remove relevant and non-redundant information also, in order to achieve the required compression. An example image of size 800 × 600 pixels at eight bits per pixel, and at 9.6 kbps take six minutes and 40 seconds to transmit. At a compression ratio of 80:1 the transmission time would be 5 s. This is a significant improvement in radio air time required, reducing the chance of intercept and reducing the security threat to the individual transmitting.

JPEG

The Joint Photographic Experts Group (JPEG) established an open algorithm for compression of still images. JPEG can achieve compression ratios of the order of 15 to 25 without significant loss of visual quality and compression up to 40:1 with only minor loss of visual quality. The image is divided into 8×8 blocks of pixels. Each block is transformed into a block of 64 coefficients using the Discrete Cosine Transform (DCT). The DCT concentrates most of the energy into a few coefficients, usually in the top-left corner of the block.

The coefficients are then quantised, which results in many zero-valued coefficients. If the coefficients are ordered using zigzag scan, then long runs of zeros are likely to occur, which facilitates entropy encoding. JPEG uses one of two entropy encoders, either Huffman coding or Arithmetic coding.

SPIHT (*S*et *P*artitioning *I*n *H*ierarchical *T*rees)

SPIHT is based on three concepts:

i) partial ordering of the image coefficients by magnitude and transmission of order by a subset partitioning algorithm that is duplicated at the decoder;
ii) ordered bit plane transmission of refinement bits, and
iii) exploitation of the self-similarity of the image Wavelet Transform across different scales.

The first step is to perform a wavelet transform. Wavelet Transforms are based on the fact that compression can be achieved by transforming the data, projecting it onto basis functions and then encoding this transform. Due to the nature of image signals and the Human Visual Response (HVS), the transform must be able to accept nonstationarity and be well localised in both the space and frequency domains. The transform must be at least biorthogonal to reduce redundancy and increase compression and finally the transform algorithm must be fast. The two dimensional Wavelet Transform satisfies each of these conditions. The wavelet transform of an image is usually represented as shown in Figure 2, and is termed the subband pyramid.

[3] http://ourworld.compuserve.com/homepages/xray_haslar/project.txt

$f^1_{LL}(x,y)$	$f^1_{LH}(x,y)$
$f^1_{HL}(x,y)$	$f^1_{HH}(x,y)$

Figure 2. First Level Wavelet Decomposition of an Image

The four subimages have the following characteristics:

f_{LL} - low frequency approximation of the image;
f_{LH} - horizontal image features emphasis;
f_{HL} - vertical image features emphasis, and
F_{HH} - diagonal image features emphasis.

The Wavelet Transform is an alternative representation of the image data but uses the same number of bits to store the data. To compress the image data, it must be decided which coefficients to send and how many bits to code them. For their programs, Said and Pearlman have used the 9/7 tap filters of the biorthogonal wavelet transform, as shown in Figure 3, and constructed a 5-level subband pyramid.

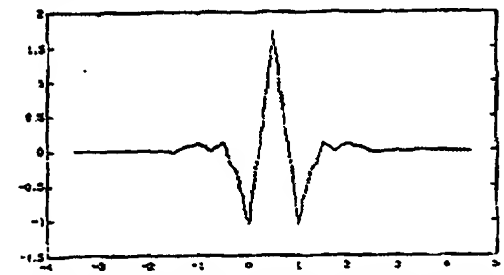

Figure 3. The Biorthogonal (9,7) Wavelet Transform

For a progressive transmission technique to be effective, it must send the most important information first. The coefficients with larger magnitude should be transmitted first because they have the larger information content. This concept has been used by other compression techniques. Said and Pearlman extended this method by ranking the binary information in the coefficient and then transmitting the most significant bits first.

The spatial orientation tree is used by Said and Pearlman to define the spatial self-similarity evident in the subband pyramid. An example of this is that large flat areas in an image can be identified in the highest level of a pyramid and once identified they can be replicated in the lower levels at the same spatial location, as shown in Figure 4. If this spatial self-similarity is used to order the coefficients by moving downward through the pyramid then this will improve the magnitude ordering of the transform coefficients.

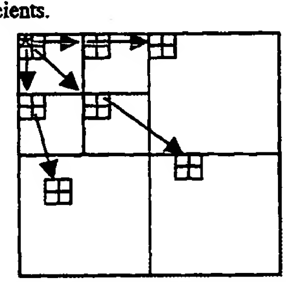

Figure 4. Spatial Tree Orientation

Said and Pearlman's subset partitioning produces extremely compact information without entropy coding which can outperform other coding techniques, including JPEG. Most other coding techniques do not compress the data but transform it to make the data more efficient for entropy coding. Like other techniques, SPIHT's compression can be improved further, by entropy coding the output of its algorithm.

Results

For our initial test, a 256 (8-bits per pixel) grey level chest x-ray image of size 320×240 pixel was used. The "dspiht" version of Said and Pearlman's SPIHT algorithm was downloaded from the Internet and used for our simulation. The JPEG program used was the one implemented in the image processing software "PMAN", version 1.55.

Figure 5 shows all the results. To obtain Figure 5b): the compression time taken by the "dspiht" algorithm on a 400 MHz Pentium II PC was 0.33s to compress the x-ray image to a bit rate of 0.1 bits per pixel; the decoding time took 0.49 s. Figure 5c) was obtained for the nearest bit rate achievable using the JPEG program. In our case this was for a Q setting of 2 and using Huffman entropy coding. Using a Q setting of "1" caused to the program to output an erroneous result. Figure 5 d) shows the case where a digital camera cannot output a raw binary image. In that case the camera's highest JPEG output setting is chosen and then the SPIHT algorithm applied to that high quality JPEG compressed image.

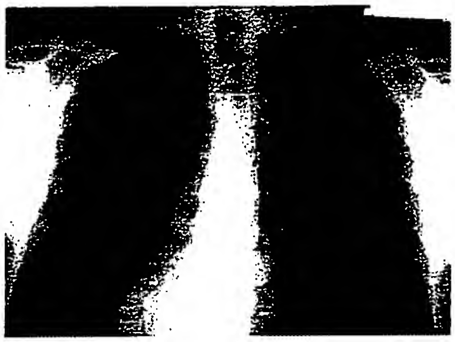

Figure 5a) Original Image: Chest X-ray

Figure 5b) SPIHT: 0.1 bpp, 36.09 dB PSNR

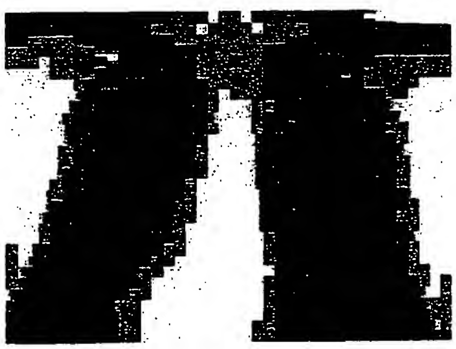

Figure 5c) JPEG: 0.15625 bpp, 23.74 dB PSNR

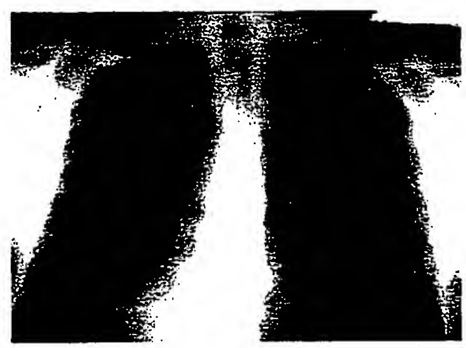

Figure 5d) SPIHT (JPEG): 0.1 bpp, 35.60 dB PSNR

The results for Figure 5d) were obtained in the following step. The raw x-ray image was coded using the JPEG algorithm on a Q (quality) setting of 100, which was the maximum possible. This produced a file with a code rate of 3.37979 bpp and a PSNR of 55.43 dB. This JPEG file was then converted into raw binary format and compressed using the SPIHT program. The resulting file when compared with Figure 5b) shows that only a loss of 0.49 dB has occurred.

Conclusions

The results clearly show the superior performance of using SPIHT coding of X-ray images compared with using the JPEG algorithm. SPIHT coding of the X-ray image at a code rate of 0.1 bpp had a PSNR of 36 dB, whereas the JPEG had a medically unusable PSNR of 23.7 dB at a code rate of 0.15625 bpp.

The results also showed that there was only a loss of 0.49 dB when SPIHT compressing a high quality JPEG coded image compared to compressing the original image. This result was shown to demonstrate that even though some digital cameras may only output JPEG images and not raw images, SPIHT can successfully be applied to high quality JPEG images. To maximise the potential of SPIHT coding it is advisable to use an adjustable compression ratio that is adjusted by the operator or can be achieved automatically by appropriate machine analysis of the image.

All of the images show the artefacts common to each of the image compression techniques analysed. JPEG produces a block artefact SPIHT seems to produce significant blurring in large flat areas in an image and slight ringing at higher compression ratios around sharp edges. The ringing is most likely caused by the use of the Wavelet Transform before set partitioning.

The military and medical doctors have a requirement for effective and efficient image compression techniques for reconnaissance, image analysis and interpretation. The image compression technique needs to be fast and achieve high compression ratios with little distortion to image quality. The aim of this project was to determine if SPIHT was suitable for telemedicine applications and compare it with JPEG. SPIHT performs considerably better than JPEG. SPIHT was able to achieve image compression ratios of up to 80:1 while maintaining an image quality suitable for military and medical use.

This high compression ratio also means very small file sizes, which is essential for the bursty nature of military transmission, and it also ensures cheaper calling costs.

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3. http://ourworld.compuserve.com/homepages/xray_haslar/project.txt